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AN ORIGINAL AMR ARCHITECTURE USING A PLC PROTOCOL

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Abstract: *In this paper is presented architecture for an AMR (Automatic Meter Reading) system using the medium for transmitting data between meters and control center the LV (low voltage) and MV (medium voltage) power lines. Aspects of operating principles, system structure, communication module and last but not least the advantages introduced by the proposed architecture are presented. To validate the system a series of field tests are presented.*

Keywords: Architecture, AMR, PLC, PRIME, transformer, system

1. INTRODUCTION

Power Line Communications (PLC) is an alternative to the currently used solutions for data transfer. PLC applications have two main uses: broadband communication networks, used in indoor power networks for data transfer between computers, and narrowband communication networks used in outdoor power lines for automatic meter reading (AMR) of electricity, water or gas. Automation of meter reading is important for power network management due to reduction of time intervention and maintenance costs of equipment and power lines, providing precise control over the entire system. An AMR system can be implemented in a entire structure of a power network of distribution and supply using the LV (low voltage), MV (medium voltage) and HV (high voltage) power lines. Solutions developed to date, using PLC communication, mainly use LV and MV power lines [1].

Such systems have been implemented in many countries worldwide, some of them are: USA, Brazil, Germany, Spain, Denmark, France, Russia, Hungary, Nigeria, Algeria, Egypt, South Africa, China, Japan, India, Korea, England, Portugal and Sweden [2].

For an AMR system to be functional is necessary that all analog meters to replace with digital meters that can be administered via a modem. For this purpose many countries have developed extensive modernization programs of meters replacement in Europe. The aim of an AMR system is not the reading of power, water or gas meter's index, but to manage them remotely using various technologies such as: PLC, WiFi, GPRS, or ZigBee [3].

PLC was originally designed to control equipments in power stations and making measurements. The first reference to this technology was made by American Institute of Electrical Engineering (AIEE) in the report "Guide to Application and Treatment of Channels for Power Line Carrier" [7]. The use of power lines raised problems from the beginning due to electromagnetic noise interference induced by the starting and stopping of electric consumers. Electromagnetic interference can have multiple sources and types such as: impulsive noise, Gaussian white noise, colored noise, quasi-synchronous noise, or synchronization noise [4]. Although this was a major disadvantage that has been identified and considered in the development of PLC, researchers have tried to find ways to increase communication distance and data speed transfer [1]. The PLC was chosen to serve two main needs: local network computer, or internet connection, and power meter reading and management. For this purpose international standards define separate communication frequency bands as follow: 1 MHz - 30 MHz (broadband) and 3 kHz - 500 kHz (narrowband). The most important bands used are: Europe - CENELEC A (3 kHz - 95 kHz), USA - FCC (10 kHz - 490 kHz), Japan - ARIBA (10 kHz - 450 kHz) and China - EPRI (3 kHz - 90 kHz).

AMR systems which use PLC have the main scope data transmission using only the power grid as a network, without the need of solutions provided by third parties. The main problem of the PLC on big distances is the presence of transformers that attenuates the transmitted signal by up to 40 dB and are a source of noise [5].

2. PROPOSED SYSTEM

Recent studies have shown the possibility of the communication over long distances, on LV and MV power lines. The problem of transformer crossing to achieve communication between the two type lines is still valid, although the use of OFDM (Orthogonal Frequency Division Multiplexing) can make communication perform successfully under certain circumstances [6,7,]. The proposed system aims to provide a solution to implement an AMR architecture that covers long distances using LV and MV power line with the possibility of transformer crossing without bypass components. With this the communication between control center and meters to be possible to be performed on power lines only as the propagation environment.

Architecture shown in Figure 1 illustrates the principle of communication between the PLC terminals installed at power meters and the control center using the data propagation environment of LV and MV power grid. The main components are: PLC modems connected to power meters, PLC concentrators with routing capability located near MV/LV transformers on MV power line and a control center connected via a PLC modem to a LV branch of power grid.

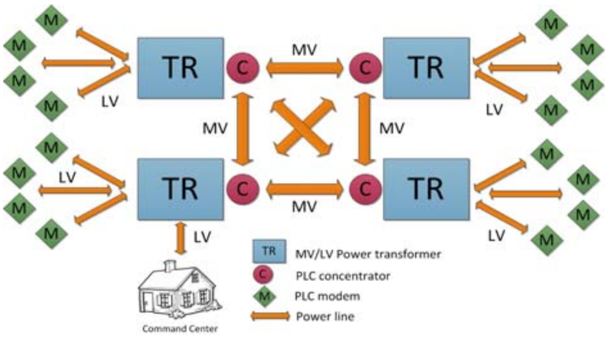

Figure 1 – Proposed architecture

Operating principle: data transfer is performed between power meters and concentrators that are located on the MV power line, between concentrators installed on MV power lines on long-distance, between command center and the nearest concentrator located on MV power line. Since the PLC can be realized on long distances using LV and MV power lines and also between them, the communication being made through the transformer's body, the installation of the concentrator on MV power line is important in terms of transfer of data between network nodes. While data transfer is achieved with difficulty through the transformer body [4], it is affordable enough to ensure communication between meters and the nearest concentrator at a time.

The existence of transformer between the concentrator and meter has the galvanic isolation effect of MV power line from noise present in the LV line. Because a concentrator can handle a high volume of meters, their number could reach 1.000 meters, it will send more easily and without loss to another concentrator located on the MV line because the power line has a lower level o f noise than the LV line. According to results presented in Chapter 3, communication can be achieved between two LV branches of a power grid via a MV power line through two MV/LV transformers [8]. Because of these issues a backup solution will always be available if a concentrator will not work and communication with related counters of the concentrator can be achieved by another concentrator or directly from the command center. The command center manages PLC network equipments status, generate invoices to customers and issue alarms if concentrators and meters are not functional or have suffered damage.

The concentrator will act as a router, so it receives data from meters modems and forwards them to the command center applying a compression algorithm to reduce the size of transmitted data, and vice-versa. The concentrator will manage counters located in the transformer secondary on which is installed using the directives received from the command center or based on the routine implemented on it. Concentrators will make constant analysis of the power system in terms of perturbation and the levels recorded will be transmitted between them so that the transmission of data to and from the command center to be made on using the network segments where noise has the lowest values or at a hour time of the day when communication conditions are suitable.

Installation of concentrators on the LV side of the transformers is not the best solution because the distance between transformer and meter is much smaller, up to 1 km, than the distance between two transformers on the MV power line as is of many km [1]. This solution can be applied only if in the grid structure the distance between MV/LV transformers is reduced. Although installation costs may be higher for the proposed system as a coupling unit for MV power line is more expensive than a coupling unit for LV power lines, this disadvantage is balanced with the reliability and successful communication between the meters and command center.

If the concentrator would be installed on the LV side of transformer, communication with it can be affected by noise in LV network when the communication with meters is made, and additional to this noise the signal sent to another concentrator will be affected by the presence of the two transformers which attenuate de signal and induce additional noise.

3. TEST SETUP

In Figure 2 a schematic diagram of communication between two PLC modems connected to the secondary windings of two MV/LV transformers is presented. The two transformers are connected through the MV power line. The transformer 1 (TR1) has an active of 400 kVA and transformer 2 (TR2) one of 250 kVA.

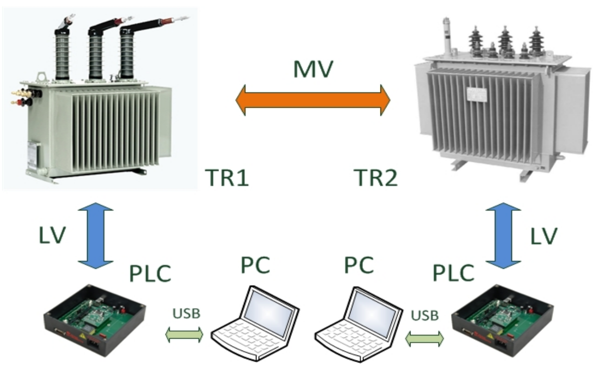

Figure 2 – PLC LV-MV-LV test

Each PLC modem is connected to a PC unit from which the data transfer is realized. The distance between the two transformers is 50m. Using PLC protocol PRIME [9] configured with FEC (Forward Error Correction) error correction type, values were obtained with data transfer and presented in

Table 2 as: modulation, SNR (Signal to Noise Ratio), BER (Bit Error Rate) and Tx (data speed transfer).

Modulation	SNR	BER	Tx
DBPSK	3 dB	0,14	5,2 kbps
DQPSK	3 dB	0,14	8,7 kbps
D8PSK	6 dB	0,17	11,8 kbps

Table 2. Test results

4. CONCLUSIONS

This paper proposes architecture for an AMR system that is based on PLC. This architecture aims to implement a management system for power meters remotely using exclusively the medium of communication of MV and LV power grid segments. Advantages of the proposed architecture are: the ability to easily expand AMR system because communication is achieved through the existing grid structure, the architecture allows integration of a large number of meters manageable by a single concentrator, standalone operating system can be made when a segment of the power grid is damaged, the architecture can be extended for control and supervision of problems that can occur in the power grid, monitoring of transformer and distribution lines, low cost because the power network is used and no third parties solution are necessary, reducing travel costs for meter reading by human operators, low error rate in automatic generation of invoices to customers.

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